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23396
ELMER GALBI
13314 VERMEER DRIVE
LAKE OSWEGO, OR 97035

FILING RECEIPT

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Applicant(s)

Alastair M. Reed, Lake Oswego, OR;

Assignment For Published Patent Application

Digimarc Corporation, Tualatin, OR;

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THIS APPLICATION IS A CON OF 09/553,084 04/19/2000 ← (Docket 60117)

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Title

Applying digital watermarks using dot gain correction

Applying Digital Watermarks using Dot Gain Correction

Related Applications:

This application is a continuation in part of co-pending U.S. patent application Serial number 09/553,084, filed 4/19/2000 (atty. docket 60117).

Field of the Invention:

The present invention relates steganography and more particularly to the digital watermarks.

Background and Summary of the Invention:

The technology for applying digital watermarks to images and to other types of data is well developed. For example see issued patent 5,748,783, issued patent 5,768,426 issued patent 5,822,435 and the references cited in these patents. Also various commercially available products (such as the widely used image editing program Photoshop™ marketed by Adobe Corporation) have image watermarking capability. There are many other patents and much technical literature available relating to the application of digital watermarks to images and to other types of data.

Co-pending application 09/553,084 describes a technique of color adaptive watermarking. With the technique described in application 09/553,084 a change in an image attribute such as luminance (or chrominance) is mapped to a change in color components such that the change is less visible. Application 09/553,084 describes the "scale to black" and the "scale to white" techniques for applying watermarks. By using the scale to white method for colors with a high yellow content such as yellow, red and green, and by using the scale to black for blue, cyan and magenta a watermark with a lower visibility and the same detect ability can be embedded in an image.

It is known that when an image is printed on a standard offset press, the relationship between the digital value of a color and the amount of ink actually applied by the press is not linear. Figures 1 illustrates the dot gain curve for a typical standard offset printing press. The horizontal axis gives a digital value of a color and the vertical axis indicates the amount of ink actually transferred by the press. The shape of the dot gain curve of offset printing presses is well known.

As a result of the dot gain curve illustrated in Figure 1, when an image containing a watermark is printed on an offset press, a watermark signal in the shadows (i.e. in an area with more ink) is reduced and a watermark signal in the highlights (i.e. in an area with less ink) is amplified. Note that the slope of the dot gain curve is different in the shadow area and in the highlight area. Thus, the same amount of change in color value produces a different amount of change in the ink applied in the two different areas. The present invention provides a technique which insures that a watermark signal is preserved in an printed image as accurately as possible not withstanding the fact that the dot gain curve of the printing press is not linear.

With the present invention, the image data is first modified in accordance with the forward dot gain curve of a printing press, next the watermark "tweak" values (i.e. the watermark change values) are calculated for this modified image data. The calculated "tweak" values are then modified in accordance with the backward dot gain curve of the printing press. The modified tweak values are then added to the original image data values to produce a watermarked image. The watermark image is then printed on the printing press. The result is that the "effective" tweak on printed paper is not materially affected by the dot gain curve of the printing press.

Brief Description of Figures:

Figure 1A shows a forward dot gain curve.

Figure 1B shows a backward dot gain curve.

Figure 2 illustrates scaling to black.

Figure 3 illustrates scaling to white.

Figure 4 is a program block flow diagram of the operation of the preferred embodiment.

Detailed Description of Embodiments:

Co-pending application Serial number 09/553,084, filed 4/19/2000 (atty docket 60117) describes a system for watermarking images. The system described in application 09/553,084 inserts watermarks in images by selecting and modifying colors to obtain approximately equal visibility for all colors. The preferred embodiment of present invention, as described herein, is described as a modification of the system described in application 09/553,084. The object of the modifications is to compensate for the dot gain curve of a printer. The entire specification of application serial number 09/553,084 is hereby incorporated herein by reference.

It is desirable that a watermark embedding algorithm produce luminance changes with approximately equal visibility through color space. Adaptive color embedding as described in application 09/553,084, selects the colors that are modified to produce a required luminance change, in a way that obtain approximately equal visibility for all colors. The dot gain correction provided by the preferred embodiment described herein approximately compensates for the non-linear effect of the printing process, so that a desired percentage change is achieved on press (that is, in the amount of ink applied to create the image). It is noted that the slope of the dot gain curve is different in the shadow area and in the highlight area. Thus, the same amount of change in color value produces a different amount of change in the ink applied in the two different areas. The preferred embodiment insures that a watermark signal (i.e. a change value) is preserved in a printed image as accurately as possible not withstanding the fact that the dot gain curve of the printing press is not linear.

As explained in application 09/553,084 a watermark can be applied to images using either a scale to black or a using a scale to white technique. With the scale to black technique, the image pixel is like a vector between black and the pixel color value. The vector is increased or decreased as shown in Figure 2. That is, Figure 2 illustrates the color changes for a luminance change utilizing the scale to black technique. The following table lists for each color, the colors that are modified as a result of a luminance change. The table also indicates the degree to which the modification is visible.

For Scale to Black:

Color	Colors Modified	Visibility of the change
yellow	cyan/magenta	high
red	cyan	high
green	magenta	medium
Blue	Yellow	low
Cyan	Magenta/yellow	low
Magenta	Cyan/yellow	low

Figure 3 illustrates the color changes that occur with a scale to white technique. The scale to white technique obtains the same luminance change as the scale to black technique; however, when scaling to white the image pixel is a vector between white and the pixel color value as shown in Figure 2. The following table lists for each color, the colors modified as the result of a luminance change. The table also indicates the degree to which the modification is visible.

For Scale to White

Color	Colors Modified	Visibility of change
yellow	yellow	low
red	magenta/yellow	low
green	cyan/yellow	medium
Blue	Cyan/magenta	high
Cyan	Cyan	high
Magenta	Magenta	medium

By using the scale to white method for colors with high yellow content such as yellow and red, and scale to black for blue, cyan, magenta and green a lower visibility mark can be made with the same detectability. Scaling to white results in the watermark being applied mainly to the dominant colors, and scaling to black implies that the watermark is mainly in the secondary colors.

When images are printed on an offset press, it is known that there is not a straight line relationship between the digital value of the color at any point in the image and the corresponding amount of ink applied to the paper at that point. This is known as dot gain. Figure 1A shows the forward dot gain curve. That is the relationship between the digital value of a color and the amount of ink actually applied. Figure 2B shows a backward dot gain curve. That is, Figure 2 indicates the value needed in order to get a particular amount of ink on the paper.

The following is a list of 256 values that generate a curve as shown in Figures 1A. That is, the following is a list of 256 positions on the vertical axis for 256 positions (i.e. for 0 to 255) on the horizontal axis.

0	7	12	18	22	26	29	32	34	37	39	42
44	46	48	50	52	54	55	57	59	60	62	64
65	67	68	70	71	73	74	76	77	78	80	81

1	83	84	85	86	88	89	90	91	93	94	95	96
2	97	99	100	101	102	103	104	105	106	108	109	
3	110	111	112	113	114	115	116	117	118	119	120	
4	121	122	123	124	125	126	127	128	129	130	131	
5	132	133	134	135	135	136	137	138	139	140	141	
6	142	143	144	144	145	146	147	148	149	150	150	
7	151	152	153	154	155	155	156	157	158	159	160	
8	160	161	162	163	164	164	165	166	167	168	168	
9	169	170	171	171	172	173	174	175	175	176	177	
10	178	178	179	180	181	181	182	183	184	184	185	
11	186	186	187	188	189	189	190	191	191	192	193	
12	194	194	195	196	196	197	198	198	199	200	201	
13	201	202	203	203	204	205	205	206	207	207	208	
14	209	209	210	211	211	212	213	213	214	215	215	
15	216	216	217	218	218	219	220	220	221	222	222	
16	223	224	224	225	225	226	227	227	228	229	229	
17	230	230	231	232	232	233	234	234	235	235	236	
18	237	237	238	238	239	240	240	241	241	242	243	
19	243	244	244	245	246	246	247	247	248	249	249	
20	250	250	251	251	252	253	253	254	254	255		
21												
22												

The following is a list of 256 values that generate the curve shown in Figure 1B. That is, the following are the vertical values for 256 positions (i.e. 0 to 255) on the horizontal axis.

26	0	1	1	1	1	1	1	1	2	2	2	2
27	2	3	3	3	3	3	3	4	4	4	4	5
28	5	5	5	6	6	6	7	7	7	8	8	9
29	9	9	10	10	11	11	11	12	12	13	13	14
30	14	15	15	16	16	17	17	18	19	19	20	20
31	21	22	22	23	23	24	25	25	26	27	27	28
32	29	29	30	31	31	32	33	34	34	35	36	36
33	37	38	39	40	40	41	42	43	44	44	45	46
34	47	48	49	49	50	51	52	53	54	55	56	57
35	57	58	59	60	61	62	63	64	65	66	67	68
36	69	70	71	72	73	74	75	76	77	78	79	80
37	81	82	83	84	86	87	88	89	90	91	92	93
38	94	96	97	98	99	100	101	103	104	105	106	
39	107	109	110	111	112	113	115	116	117	118	120	
40	121	122	123	125	126	127	129	130	131	132	134	
41	135	136	138	139	140	142	143	144	146	147	149	
42	150	151	153	154	156	157	158	160	161	163	164	

166	167	168	170	171	173	174	176	177	179	180
182	183	185	186	188	189	191	193	194	196	197
199	200	202	203	205	207	208	210	211	213	215
216	218	219	221	223	224	226	228	229	231	233
234	236	238	239	241	243	244	246	248	250	251
253	255									

It is noted that different offset processes produce different amounts of dot gain; however, with most offset processes, the dot gain curve has the shape shown. For some particular offset processes, the actual values may to 50 or 75 percent of the values given above. The values used in any particular application should be the values appropriate for the particular printing process that will be used to print a particular image.

Figure 4 is a block program flow diagram of a program for the preferred embodiment of the invention. The process begins with an image 401 which is in the CYMK color space. As indicated by block 402, the values for each color in the image are first modified in accordance with the values of the forward dot gain curve. This generates a modified image.

Next as indicated by block 403 calculations are made using the modified image to determine the "tweak" (i.e. the change) values needed to embed a particular watermark in the modified image. This calculation can be done using known watermarking techniques. In the preferred embodiment, the tweak values are calculated using the technique available in the commercially available Photoshop image editing program. However, in other embodiments, other watermarking techniques can be used.

The tweak values are next modified in accordance with the backward dot gain curve values as indicated by block 404. Next as indicated by block 405, the modified tweak values are added to the values in the original image 401, thereby producing a watermarked image. Finally as indicated by block 406 the watermarked image is

printed using an offset press which has the forward and backward dot gain values used in blocks 402 and 404.

The watermark can then be read from the printed image using known watermarks reading techniques.

In an alternate embodiment of the invention, the tweak values are added to the modified image values and then the resultant image is modified in accordance with the backward dot gain curve values; however, it has been found that in most instances, the process described in Figure 4 eliminates some rounding errors.

In some applications, it has been found desirable to add back a constant that controls the amount of the scale to black signal when a color with high yellow-blue saturation is being embedded. This is sometime necessary, since some cameras are insensitive in the blue channel, so changes in yellow are not detected very well.

In general to dot gain correction is only applied to the CMY channels, and not to K channel. However, if desired the dot gain correction can be applied to all the channels.

The preferred embodiments described above relate to the dot gain curve for offset printing processes. It is noted that other processes such as ink jet printing have a different type of dot gain curve. The invention can be applied to most types of printing processes by merely using a dot gain curve appropriate to the particular process.

Images watermarked using the embodiments described above can be read with conventional watermark reading techniques. Naturally as is conventional the watermark reading technique used should coincide with the particular technique used to generate the change values , that is, with the technique used to watermark

the image.

While the invention has been described with respect to watermarking images it should be understood that the principle is applicable to other types of data.

The preferred embodiment relates to an image in the CYMK color space. Other embodiments using the same principles can operate on images in various other color spaces.

While the invention has been shown and described with respect to preferred embodiments, it should be understood that various changes in form and detail may be make without departing from the spirit and scope to the invention. The scope of the invention is limited only by the appended claims.

I claim:

1) A method of watermarking an image comprising the steps of
modifying said image in accordance with the values in a forward dot gain curve,
calculating change values necessary to watermark said modified image,
modifying said change values in accordance with a backward dot gain curve, and
combining said modified dot gain values and said image to produce a watermarked image.

2) A system for watermarking an image comprising,
means for modifying said image in accordance with a forward dot gain curve,
means for generating change values needed to watermark said modified image with a particular watermark,
means for calculating change values necessary to watermark said modified image,
means for modifying said change values in accordance with a backward dot gain curve, and
means for combining said modified dot gain values and said image to produce a watermarked image.

3) The method recited in claim 1 wherein said dot gain curve is the dot gain curve associated with an offset printing press.

4) The system recited in claim 2 wherein said dot gain curve is the dot gain curve associated with an offset printing press.

5) The method recited in claim 1 wherein said backward dot gain curve is the inverse of said forward dot gain curve.

6) The system recited in claim 2 wherein said backward dot gain curve is the inverse of said forward dot gain curve.

7) The method recited in claim 1 wherein said image includes CYMK (cyan yellow, magenta, and black) colors.

8) The system recited in claim 2 wherein said image includes CYMK (cyan yellow, magenta, and black) colors.

9) The method of claim 1 wherein said image is watermarked using the scale to black technique.

10) The method recited in claim 1 wherein said image is watermarked using the scale to white technique.

11) A method of watermarking an image which will be printed on an offset printing press comprising the steps of
modifying said image in accordance with the values a forward dot gain curve applicable to said offset printing press,
calculating change the values necessary to watermark said modified image with a particular watermark,
modifying said change values in accordance with the backward dot gain curve of said offset printing press,
combining said modified dot gain values and said image to produce a watermarked image, and
printing said watermarked image on said offset press.

12)) A method of processing an image comprising the steps of
modifying said image in accordance with the values in a forward dot gain curve,
calculating change values necessary to watermark said modified image with a particular watermark,
modifying said change values in accordance with a backward dot gain curve,
combining said modified dot gain values and said image to produce a watermarked image,

printing said watermarked image, and
reading the watermark in said printed image.

13) The method recited in claim 12 wherein said image is printed on an offset press.

14) The method recited in claim 13 wherein said dot gain curves are the dot gain curves of said offset press.

15) A method of watermarking an image with a particular watermark prior to printing by an offset press comprising the steps of,
calculating the tweak values needed to embed said particular watermark in said image,
changing the color values of said image by an amount which results in changes in ink value equal to said tweak values,
whereby said image is watermarked with said particular watermark when printed on said offset press.

Abstract:

The color values in an image data are first modified in accordance with the forward dot gain curve of an offset printing press, next the watermark "tweak" values (i.e. the watermark signal values) are calculated for this modified image data. The calculated "tweak" values are then modified in accordance with the backward dot gain values of the printing press. The modified tweak values are then added to the original image data values. The image is then printed on the offset printing press. The result is that the "effective" watermark tweak on the printed paper is not materially affected by the dot gain curve of the printing press.

Figure 1A: Forward Dot Gain Correction Curve

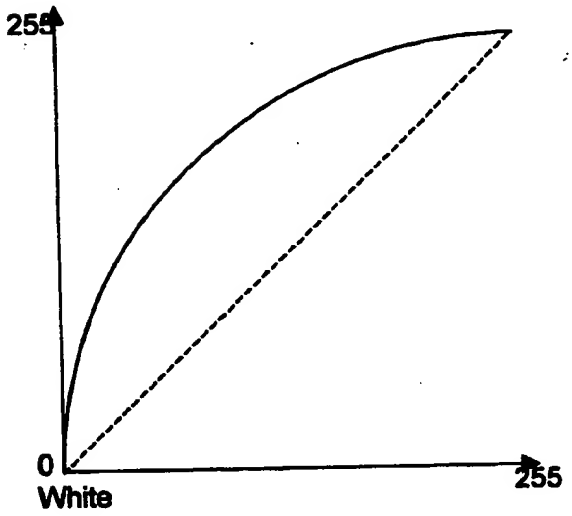


Figure 1B Backward Dot Gain Correction Curve

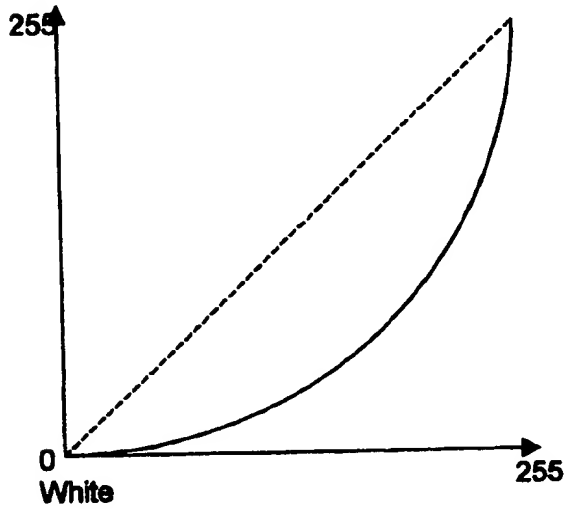


Figure 2: Present Scaling Towards Black

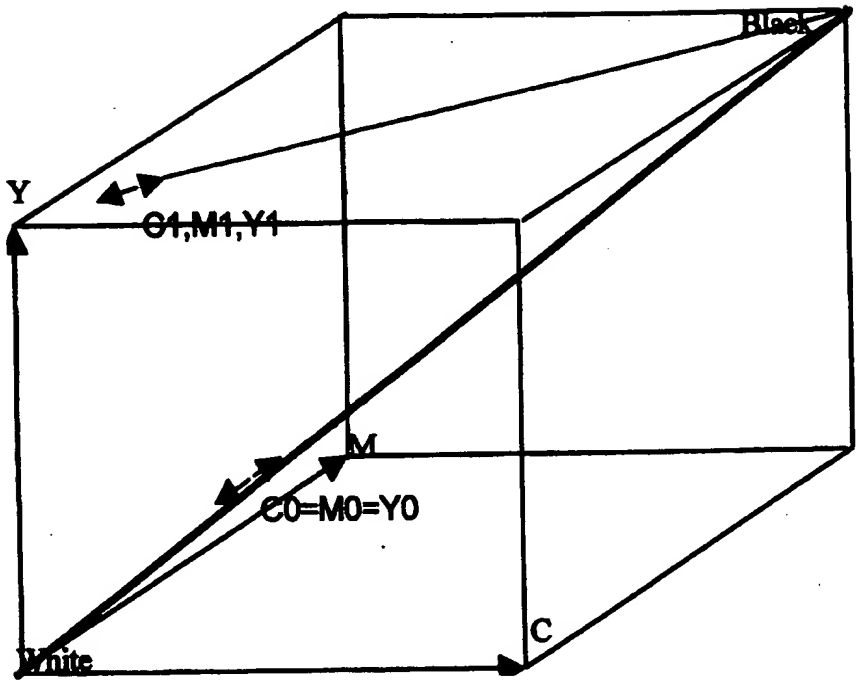


Figure 3: Scaling Towards White

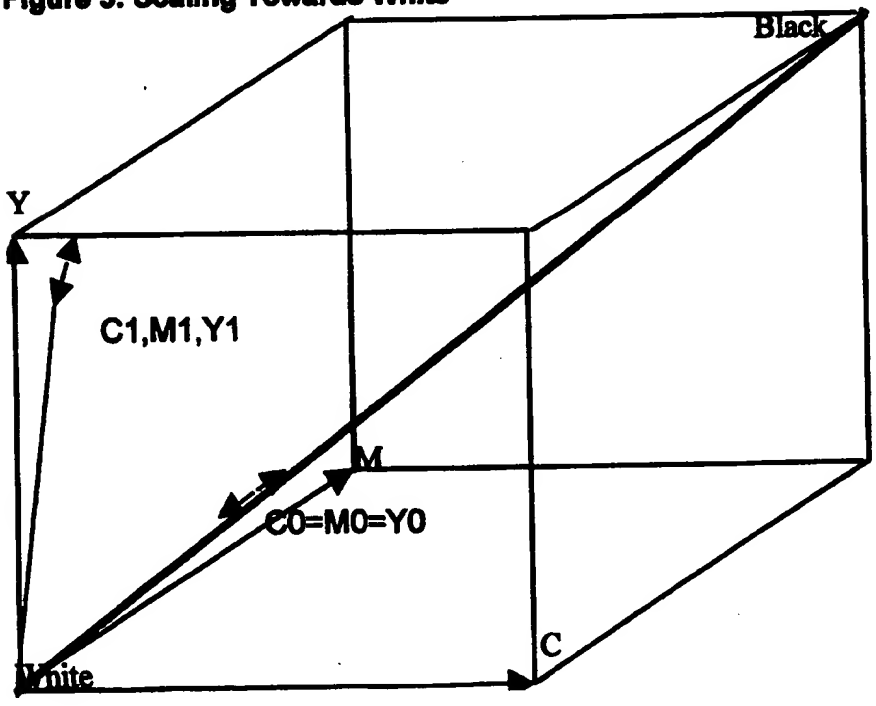
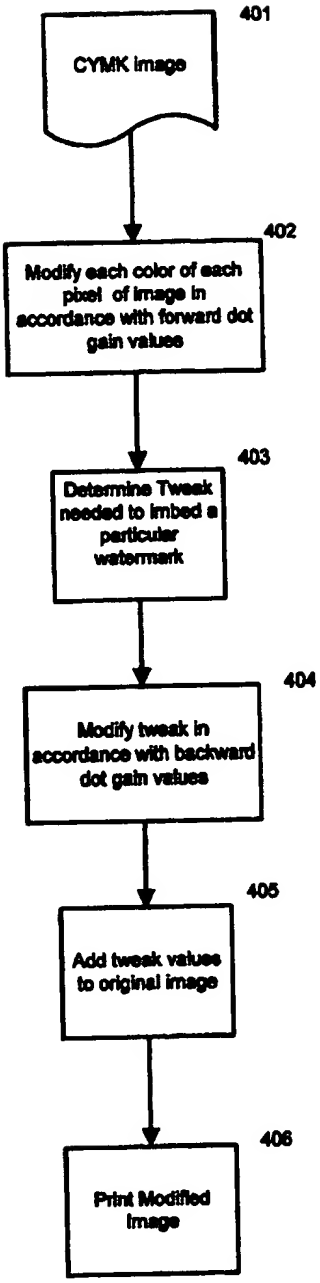


Figure 4


401
CYMK image
402
Modify each color of each pixel of image in accordance with forward dot gain values
403
Determine Tweak needed to imbed a particular watermark
404
Modify tweak in accordance with backward dot gain values
405
Add tweak values to original image
406
Print Modified Image